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Floral and Ecological Features of *Eriocaulon atrum* Nakai and Its Close-Allies in Yakushima Island, Southern Japan

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Eriocaulon atrum and its allied species were studied on Yakushima Island, based on floral and ecological features. *Eriocaulon hananoegoense* Masam., which being known as endemic to Yakushima Island, is not distinguished from *E. atrum*. The occurrence of *E. kiusianum* Maxim. in Yakushima Island is reported for the first time. *Eriocaulon atrum* and *E. kiusianum* have different ecological features.

Key words: Eriocanlon, Eriocaulaceae, Yakushima Island.

Eriocaulon atrum Nakai is characterized by the connate sepals, the involucral bracts shorter than the head, and the blackish bracts and calyces. In Yakushima Island, *E. atrum* grows in bogs or marsh places in sites at elevations of 1500 m or more. Masamune (1929) was the first botanist who noticed it in Yakushima Island, and determined it as *E. atrum* Nakai. Later he regarded it as an endemic species of the island and named it *E. hananoegoense* (Masamune 1934). Satake (1940, 1941 and 1982) distinguished *E. hananoegoense* from *E. atrum* by the presence of glandular hairs composed of two cells on the outer apical portion of bracts of staminate flowers, the obtuse apex of the median calyx lobe of pistillate flowers and the glabrous receptacle. However, these characters in the other species are insufficient as diagnostic characters because of their instability and variability (Miyamoto and Ohba 2000), and *E. hananoegoense* was treated as the synonym of *E. atrum* by Miyamoto and Ohba (1998), while in Yakushima Island, there is an *Eriocaulon* that is not yet known.

The paper aims to provide floral and ecological features to make clear taxonomic problems of *Eriocaulon* in Yakushima Island.

Materials and Methods

Sampling covered 23 populations from five different localities in Yakushima Island, Kagoshima Pref., and in order to clarify taxonomic positions, collections were done at Homan-cho, Fukuoka Pref., Mt. Kirishima, Miyazaki Pref., Mt. Kuju, Oita Pref., Kyushu (Table 1). All materials were collected from 50 × 50 cm quadrates, and they were pressed and dried. In this paper each quadrate is regarded as a single population. Floral morphological features were represented by all flowers in a head of the longest scape in each of all the individuals. They were observed under a binocular microscope with camera lucida. Voucher specimens are deposited in the Herbarium of the

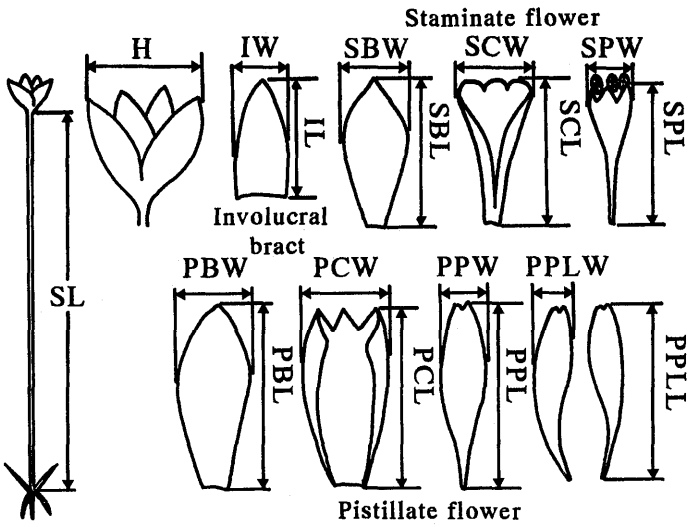

Fig. 1. Parts measured: 1) H: Width of head. 2) IL: Length of involucral bract. 3) IW: Width of involucral bract. Pistillate flower. 4) PBL: Length of bract. 5) PBW: Width of bract. 6) PCL: Length of calyx. 7) PCW: Width of calyx. 8) PPL: Length of petal of central part. 9) PPW: Width of petal of central part. 10) PPLL: Mean length of petal of lateral part. 11) PPLW: Mean width of petal of lateral part. Staminate flower. 12) SBL: Length of bract. 13) SBW: Width of bract. 14) SCL: Length of calyx. 15) SCW: Width of calyx. 16) SPL: Length of petal. 17) SPW: Width of petal. 18) SL: Length of the longest scape in each individual.

University of Tokyo (TI).

For investigating variation, measurements and sketches were done in 265 individuals, of which 180 (in 23 populations) were from Yakushima Island, 30 (in two populations) from Homan-cho, 25 (in two populations) from Mt. Kirishima and 30 (in two populations) from Mt. Kuju.

Eighteen floral characters were meaured (Fig. 1). Observations were also made of the hairiness of receptacles, calyces and petals of pistillate flowers, and the glandular hairs on bracts, calyces and petals of both staminate and pistillate flowers.

Ecological and individual disposition of *Eriocaulon* was surveyed in a 100 × 20 cm quadrate at Shohananoego moor (alt. 1600 m) in Yakushima Island.

Result

Principal component analysis

The cumulative variance of the first three principal components and loadings of eighteen floral characters are shown in Table 2. The first to third principal components contained 79 % of the total variance. The first component accounted for 66 % of the total variance. Characters with heavy loadings in the first component were all characters except for SL, especially PCL, PPL, PPLL and SCL had loadings above 0.9 (abbreviation indicated in Fig. 1). These characters were length characters in the flower. The second component accounted for 9 % of the total variance. SL loading expressing plant size was heavy in the second component. The third component accounted for 4 % of the total variation, however, all characters had

Table 1. List of localities of populations examined

Locality	Voucher specimen
Shohananoego, alt. 1600 m, Yakushima Island, Kagoshima Pref.	92001
	92002
	92005
	92036
	92048
Hananoego, alt. 1600 m, Yakushima Island	92049
	92006
	92007
	92040
Nageishi moor, alt. 1740 m, Yakushima Island	92013
	92014
	92015
	92032
Between Mt. Miyanoura and Mt. Nagata, alt. 1720 m, Yakusima Island	92026
	92027
	92028
	92033
	92034
Shikanosawa, alt. 1520 m, Yakushima Island	92017
	92018
	92021
	92022
	92023
Babazutsumi, Honamicho, alt. 60 m, Fukuoka Pref.	92108
	92112
Miike, alt. 1250 m, Mt. Kuju, Oita Pref.	92066
	92067
Byakushiike, alt. 1200 m, Mt. Kirishima, Miyazaki Pref.	92101
	92102

negative loading.

The scatter diagram of the first principal component to the second (Fig. 2) shows that *Eriocaulon* had wide range of variations both in the first and second components. However, they were clearly segregated two dimensions, of right and left sides by first component. The populations in Yakushima Island (92001, 92006, 92013, 92014, 92017, 92021, 92023, 92026, 92032, 92033, 92040 and 92048) and Mt. Kuju (92066, 92067) were concentrated on the right side. The Yakushima Island (92002, 92005, 92007, 92015, 92018, 92022, 92027, 92028, 92034, 92036 and 92049), Homan-cho (92108 and 92112) and Mt. Kirishima (92101 and 92102) were concentrated on the left side (Fig. 2).

Floral morphology

Figures 3 and 4 show variations of floral features within a single population at Nageishi moor (Fig. 3) and Shohananoego moor (Fig. 4). The number of flowers within a single head varied between 4 and 16. The heads were turbinate (Figs. 3A, 4A). The involucral bracts were apparently shorter than the flowers or nearly the same in length and ovate to elliptic in shape (Figs. 3B, 4B). The shape of bracts on pistillate flowers was ovate to obovate (Figs. 3C and 4C) and that of staminate flowers was oblanceolate (Figs.

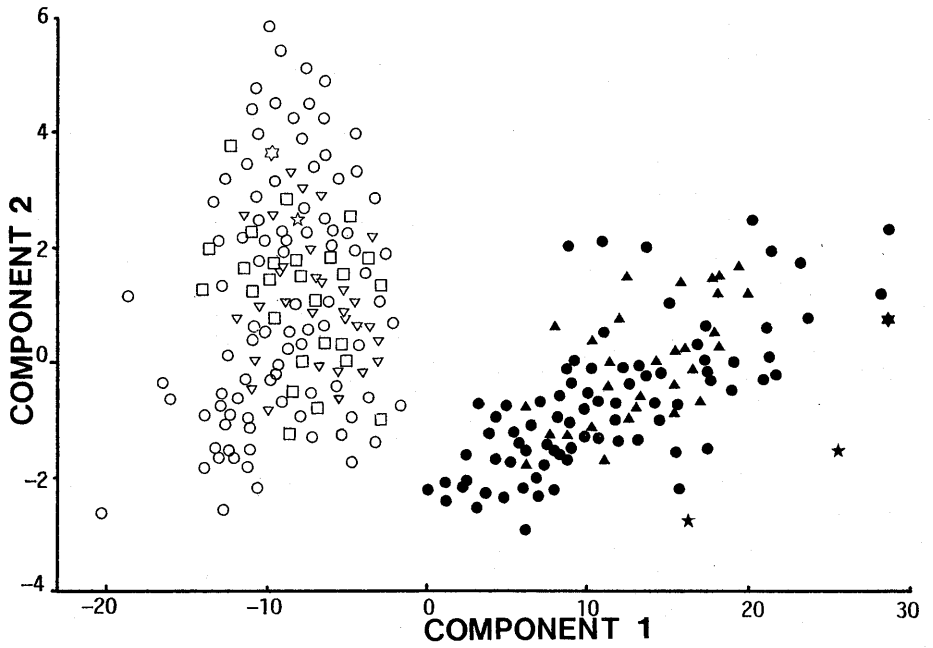

Fig. 2. Scatter diagram of the first principal component to the second. ○, ●: Yakushima Island. □: Mt. Kirishima, Miyazaki Prefecture. ▲: Mt. Kuju, Oita Prefecture. ▽: Honamicho, Fukuoka Prefecture. ★ (left): lectotype of *Eriocaulon hananoegoense* (Masamune, TI). ★ (right): holotype of E. glaberrimum (Tatewaki 64490, TNS). ★ lectotype of *E. atrum* (Kodama, TI). ☆: syntype of *E. atrum* (Funabashi, TI). ☆: holotype of *E. kiusianum* (Maximowicz, LE). White: sessile type on median petal of pistillate flower. Black: clawed type on median petal of pistillate flower.

3G, 4G). Calyces in pistillate flowers were elliptic to obovate in shape and those of staminate flowers were oblanceolate in shape. The calyces of both pistillate and staminate flowers were always trifid with blackish apices (D, H in Figs. 3, 4). The median calyx lobes were always acute. The median petals of pistillate flowers were apparently clawed (here named clawed type; Fig. 3E) or sessile (named sessile type; Fig. 4E). These were constant and stable in each population. The clawed type occurred in 92001, 92006, 92013, 92014, 92017, 92021, 92023, 92026, 92032, 92033, 92040 and 92048. The sessile type occuured in 92002, 92005, 92007, 92015, 92018, 92022, 92027, 92028, 92034, 92036 and 92049. The corollas of staminate flowers were tubular with a trifid apex. (Figs. 3I, 4I). The petals and calyx of pistillate flowers were hairy (Figs. 3D, E, F) or glabrous to almost glabrous on their abaxial side (Figs. 4D, E, F). The indumenta on receptacles varied from hairy to glabrous. Sometimes glandular hairs were observed on the apical part of the bracts of staminate flowers. *Eriocaulon* from the populations of Mt. Kuju was the clawed type and those from Homan-cho and Mt. Kirishima was the sessile type. Both clawed and sessile types were found in all localities in Yakushima Island.

Individual disposition of *Eriocaulon* in Yakushima Island

Figure 5 shows individual disposition in a 100 × 20 cm quadrate. The water depth of

Table 2. Cumulative variance of the first three principal comonents and the loadings of 18 characters on each principal component. Character's abbreviation is indicated in Fig. 1

Cumulative Variance	C 1 66%	C 2 75%	C3 79%
H	0.619	0.553	–0.083
IL	0.737	0.178	–0.540
IW	0.633	0.478	–0.152
PBL	0.789	0.183	0.208
PBW	0.758	0.090	–0.355
PCL	0.911	0.084	0.043
PCW	0.852	0.106	–0.136
PPL	0.934	0.055	0.179
PPW	0.896	0.214	–0.051
PPLL	0.917	–0.007	0.171
PPLW	0.872	–0.251	0.052
SBL	0.900	–0.014	0.011
SBW	0.808	–0.111	–0.244
SCL	0.919	–0.027	0.046
SCW	0.858	–0.209	–0.237
SPL	0.883	–0.068	0.078
SPW	0.769	–0.277	–0.317
SL	–0.276	0.813	–0.145

the moor reached 24 cm. Seventy eight individuals of *Eriocaulon* were found from the marsh to the submerged slopes in the quadrate. The length of scape varied from 4 cm to 24 cm, and 37 individuals of the sessile type varied from 8 cm to 24 cm, while 41 individuals of the clawed type were from 4 cm to 8 cm long (Fig. 5).

Discussion

The clawed type and the sessile type are quite distinct and distinguished from one another by the shape of the petals of pistillate flowers. These were distinguishable by the size of flowers. The flowers of the sessile type are smaller than those of the clawed type (Fig. 2, clawed type on right side, sessile type on left side). Both of these types are found in Yakushima Island.

The lectotype (Akanumanohara, Tochigi Pref.) of *E. atrum* Nakai and the lectotype of *E. hananoegoense* Masam. fall within the variation range of the clawed type. While the syntype (Mamushiike, Aichi Pref.) of *E. atrum* and the holotype of *E. kiusianum* Maxim. are of the sessile type (Fig. 2). Satake (1940) distinguished *E. hananoegoense* from *E. atrum* by its acute median calyx lobes on pistillate flowers and sparse, two-celled glandular hairs on the bracts of staminate and pistillate flowers. These characters, however, overlap each other and cannot be used as diagnostic characters.

The lectotype of *E. hananoegoense* is evidently merely a dwarf individual of *E. atrum*. These from Mt. Kuju were also *E. atrum* in having clawed median petals of pistillate flowers. The known distribution range of *E. atrum* is in central and northern Kanagawa Pref. *Eriocaulon atrum* of Mt. Kuju and Yakushima Island reveals disjunctive distribution. The sessile type is *E. kiusianum* Maxim. *Eriocaulon kiusianum* was described from Shimabara, Nagasaki Pref., Kyushu. *Eriocaulon nakasimanum* Satake is a synonym of *E. kiusianum* Maxim. (Ohba and Miyamoto 1993).

Eriocaulon atrum and *E. kiusianum* were found in the same population in Yakushima Island, and there was no division (Fig. 5). The length of scapes of *E. kiusianum* is very variable, and seems to vary depending on the depth of water. In shallow water places or marshes, the length of scapes were up to 10 cm (Figs. 6-1, 2, 3), while in submerged places they become 24 cm (Fig. 6-4). However, the length of scapes of *E. atrum* are less variable, they do not exceed 8 cm long even these found in deeply submerged places. In Yakushima Island and Mt. Kirishima, *E. kiusianum* was often found in ponds, with the flowers held above the water surface. The scape of *Eriocaulon kiusianum* lengthens according to the depth of water.

Taxonomic treatment

Eriocaulon atrum Nakai in Repert. Spec. Nov. Regni Veg. **9**: 466 (1911). Type: Japan.

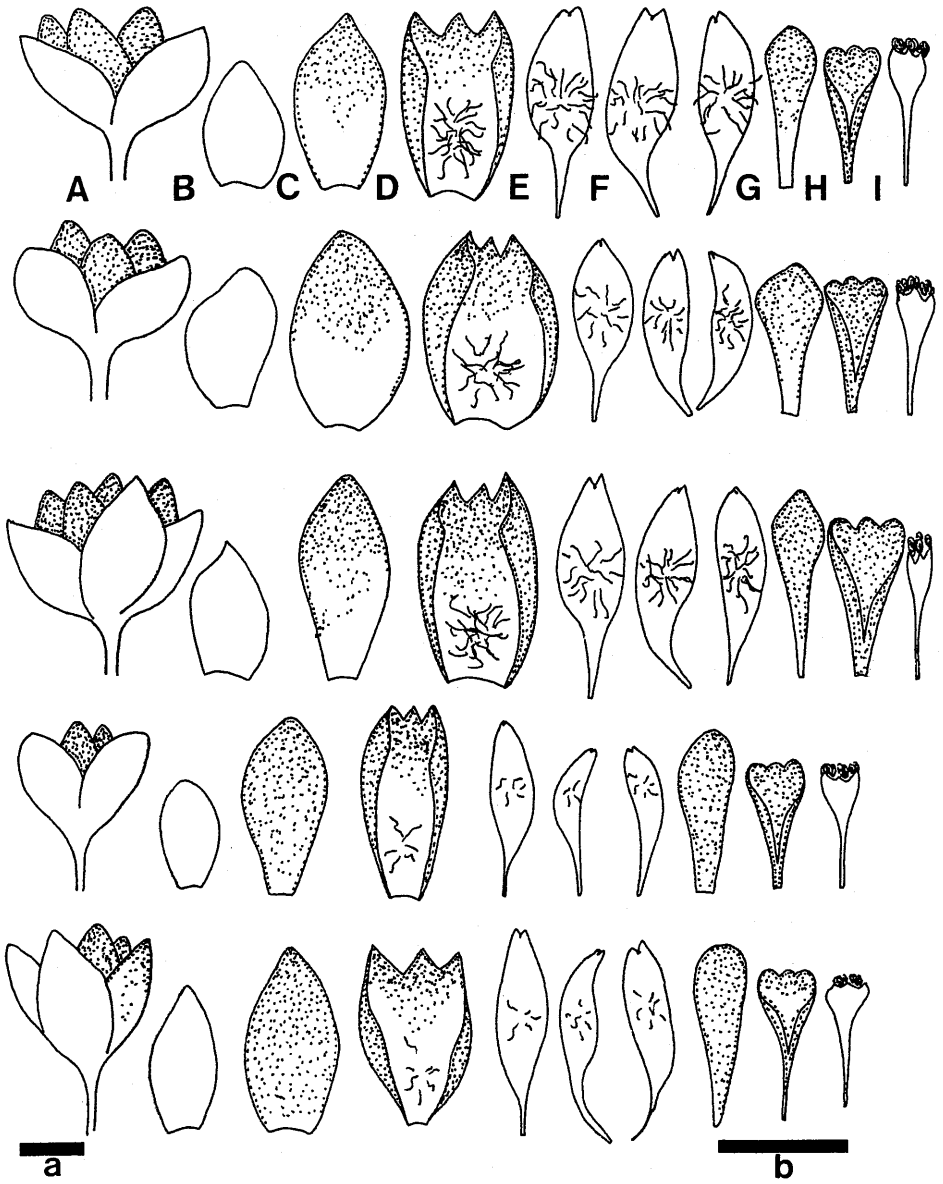

Fig. 3. Morphological flower of individual variation in the population. (Nageish moor 92013). A: head. B: involucral bract. Pistillate flower. C: bract. D: calyx. E: median petal. F: lateral petal. Staminate flower. G: bract. H: calyx. I: petal and anthers. Scale bar represents 1 mm. a for A; b for B, C, D, E, F, G, H and I.

Tochigi Pref., Akanumanohara, Nikko, S. Kodama, Aug. 1910 (TI–lectotype, selected here).

E. glaberrimum Miyabe & Satake in Acta Phytotax. Geobot. **13**: 280 (1943). Type: Japan. Hokkaido, Nemuro prov., Otiisi, M. Tatewaki 64490, Aug. 1934 (TNS).

E. atrum Nakai var. *glaberrimum* (Satake)

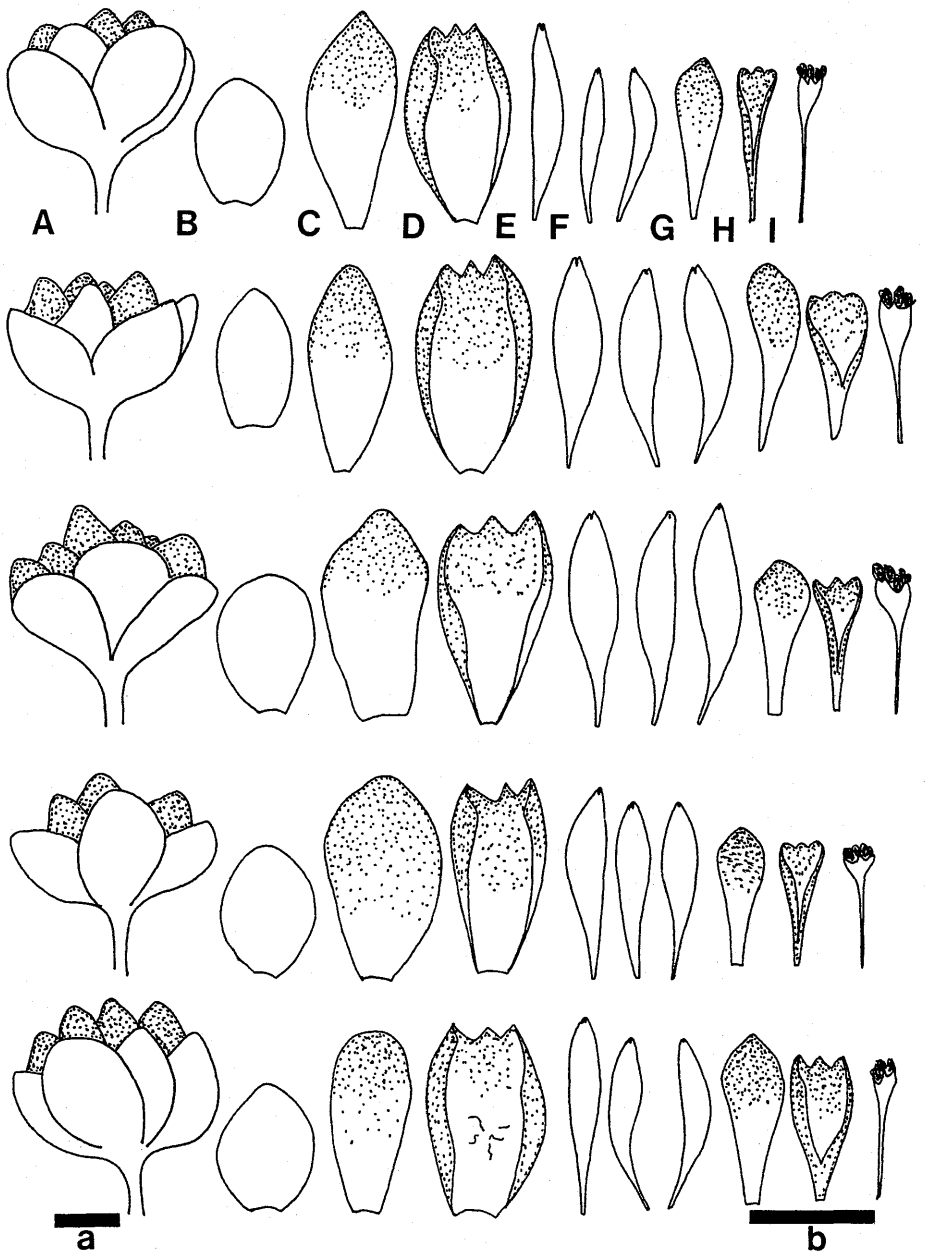

Fig. 4. Variation in flower morphology in a single population. (Shohananoego 92005). A: head. B: involucral bract. Pistillate flower. C: bract. D: calyx. E: median petal. F: lateral petal. Staminate flower. G: bract. H: calyx. I: petal and anthers. Scale bar represents 1 mm. a for A; b for B, C, D, E, F, G, H and I.

T. Koyama in Ohwi, Fl. Jap., Engl. ed.: 270 (1965).

E. hananoegoense Masam. in Mem. Fac. Sci. Agr. Taihoku Imp. Univ. **11**: 537 (1934). Type: Japan. Kagoshima Pref., Yakushima, Masamune s. n., 30 Aug. 1926

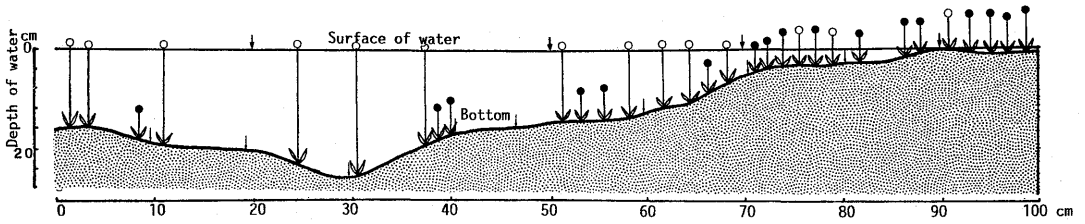

Fig. 5. Profile of the individual disposition in a 100 × 20 cm quadrate at Shohananoego moor. White circles: sessile on median petal of pistillate flower. Black circles: clawed on median petal of pistillate flower.

(TI–lectotype, selected by Miyamoto and Ohba 1998).

E. atrum auct. non Nakai: Masam., Prel. Rep. Veg. Yakusima: 51 (1929).

E. atrum Nakai var. *hananoegoense* (Masam.) T. Koyama in Ohwi, Fl. Jap. Engl. ed.: 270 (1965).

Jap. name: Kuro-inunohige.

Distribution: Hokkaido, Honshu and Kyushu.

Eriocaulon kiusianum Maxim. in Bull. Acad. Sci. St.-Pétersb. **8**: 22 (1892). Type: Japan. Nagasaki, Simabara, C. J. Maximowicz s. n., 20 Sept. 1863 (LE–holotype, BM, K–isotypes).

E. atrum Nakai var. *intermedium* Nakai ex Satake in J. Jpn. Bot. **15**: 142 (1939). Type: Okayama Pref. [Bittyu], Kibi-gun, Keyaki, Z. Yoshino 30, Oct. 1935 (TI–holotype). Paratype: Wakayama Pref. [Kii], Nishimuro-gun, Shinzyo-mura, T. Nakazima s. n., Oct. 1925 (TI). Osaka Pref. [Settu], Toyonaka-mati, N. Ui 21, 23 Aug. 1934 (TI). Hyogo Pref. [Harima], Kato-gun, Onomati. collector unknown 21 (TI).

E. atrum Nakai var. *platypetalum* Satake in J. Jpn. Bot. **15**: 632 (1939). Type: Corea [Tyosen], Saisyu-to [Cheju do], E. Taquet 6189, Sept. 1912 (TI).

E. glaberrimum Miyabe & Satake var. *platypetalum* (Satake) Satake in Acta Phytotax. Geobot **13**: 281 (1943).

E. nakasimanum Satake in J. Jpn. Bot. **15**: 143 (1939). Type: Japan. Fukuoka Pref. [Tikuzen], Yakatabaru, K. Nakashima 49, Oct. 1937 (TI–holotype).

E. nanellum var. *piliferum* Satake in J. Jpn. Bot. **49**: 314 (1974). Type: Japan. Tochigi Pref. Shioya-gun, Shiobara-cho, Konuma moor, alt. 970 m, B. Kawamura 316852, 7 Aug. 1973 (TNS–holotype, TI–isotype).

E. nasuense Satake in J. Jpn. Bot. **46**: 110, f. 1, 2 (1971). Type: Japan. Tochigi Pref., Minami-Kanamaru, near Otawara city, B. Kawamura 271724, 11 Oct. 1970 (TNS–holotype).

Jap. name: Tsukushi-kuro-inunohige.

Distribution: Honshu and Kyushu.

The examined specimens were cited in Miyamoto and Ohba (1998).

We greatly appreciate Professor Tetsukazu Yahara, Kyushu University for his valuable information on *Eriocaulon* in Yakushima Island.

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Miyamoto F. and Ohba H. 1998. Biogeography and Taxonomy of *Eriocaulon atrum* Nakai and *E. kiusianum* Maximowicz (Eriocaulaceae). Univ. Mus., Univ. Tokyo, Bull. **37**: 153–170.

—— and —— 2000. Populational variation of floral

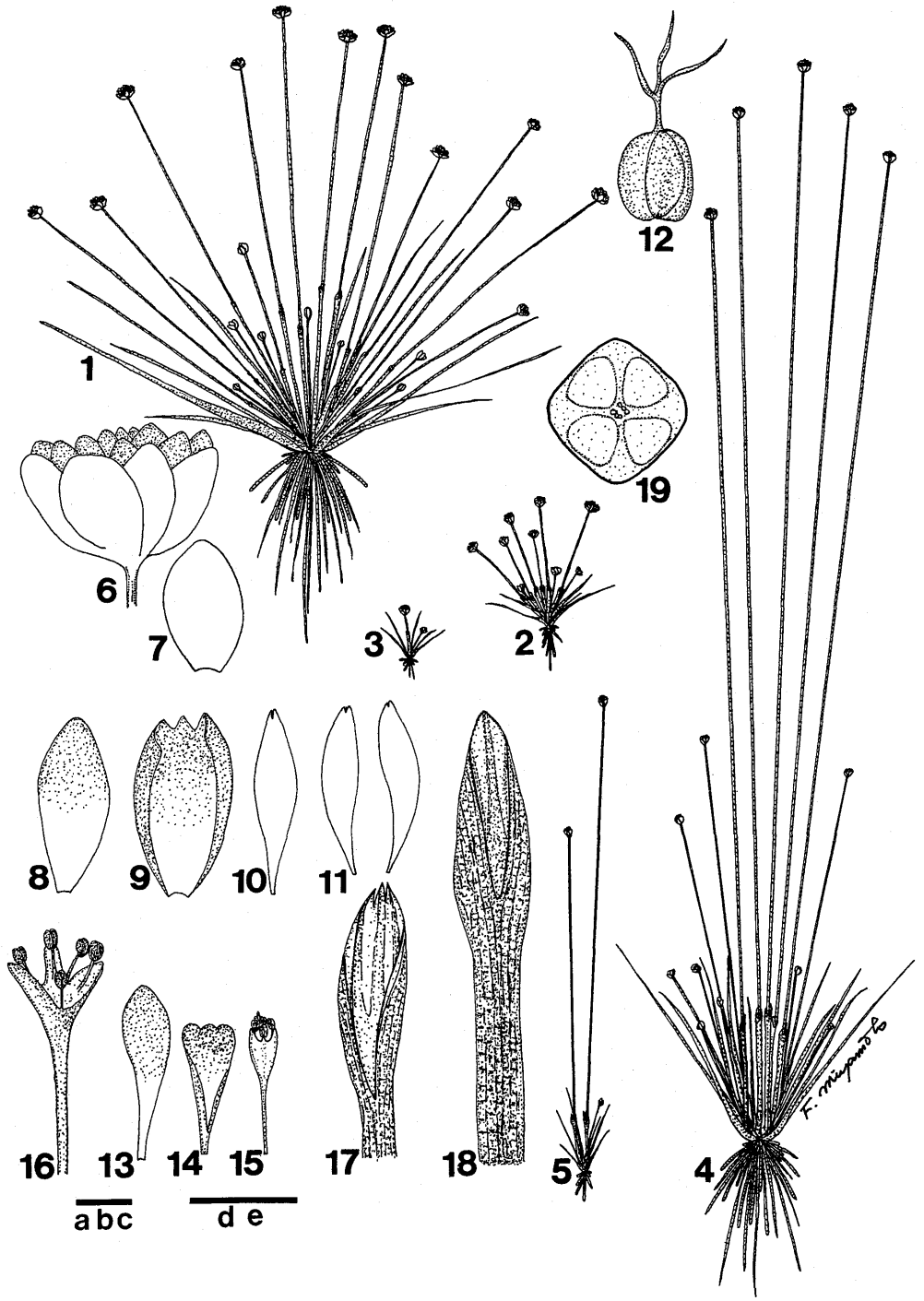

Fig. 6. *Eriocaulon kiusianum* Maxim. in Yakushima Island. 1–3: shallow water habit. 4–5: submerged habit. 6: head. 7: involucral bract. Pistillate flower. 8: bract. 9: calyx. 10: median petal. 11: lateral petals. 12: ovary and stigmas. Staminate flower. 13: bract. 14: calyx. 15, 16: petal and anthers. 17, 18: sheath. 19: cross section of scape. 1, 6–19: Shohananoego (2059). 2: Hananoego (2051). 3: Shikanosawa (2033–1), 4–5: Shohananoego (2047). Scales: a (1 cm) for 1–5, b (1 mm) for 8–11, 13–15, c (0.1 mm) for 19, d, (1 mm) for 6, 7, 17 and 18, e (0.5 mm) for 12 and 16.

characters of *Eriocaulon mikawanum* Satake & T.Koyama and *E. miquelianum* Körn. (Eriocaulaceae). Taxonomical Studies of *Eriocaulon* in Japan I. J. Agri. Sci., Tokyo Nogyo Daigaku **44**: 241–251.

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宮本　太[a]，大場秀章[b]：**屋久島産クロイヌノヒゲとその近縁種の花形態および生態的特性**

本研究は鹿児島県屋久島に生育するクロイヌノヒゲ *Eriocaulon atrum* Nakai とツクシクロイヌノヒゲ *E. kiusianum* Maxim.について花形態および生育地における生態特性を明らかにした．特産種として屋久島から記載されたヤクシマホシクサ *E. hananoegoense* Masam.はクロイヌノヒゲの矮小型にすぎないことが明らかになった．また，屋久島の標高1600 m 以上の高所にクロイヌノヒゲと同所的に生育する近縁種は，雌花花弁基部が無柄であること，花サイズがクロイヌヒゲに比べて小さいことで区別できる．これらの分類学的扱いを明らかにするために宮崎県霧島山，大分県久住山および福岡県産の個体群，およびクロイヌノヒゲとツクシクロイヌノヒゲのタイプ標本を含めて比較検討した．その結果，雌花花弁基部が無柄の個体群と霧島および福岡県産の個体群はツクシクロイヌノヒゲと雌花花弁の形態と花サイズが一致することが明らかになった．また大分県久住山の個体群は雌花花弁に柄を有することなどからクロイヌノヒゲであることが明らかになった．屋久島におけるクロイヌノヒゲとツクシクロイヌノヒゲにはすみ分けは見られなかった．しかし，花茎長の長さで両種には明らかな生育地での差異が見られた．ツクシクロイノヒゲでは最高24 cm の花茎をもち，頭花は水面上に出していた．それに対しクロイヌノヒゲではその長さが最高 8 cm であった．これらのことからツクシクロイヌノヒゲは水深にたいして花茎を伸長させる性質を示すが，クロイヌノヒゲはそのような伸長が見られないことが明らかになった．

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